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(54) **Gas sensors**

(57) A gas sensor suitable for operation at a fixed temperature above ambient temperature comprises a gas sensitive MOSFET (10) which is maintained at the elevated temperature by virtue of the heat dissipated in the drain source path. A feedback circuit is provided for maintaining the power dissipation at a substantially fixed level, the source substrate diode (S-SB) of the device being used as a temperature sensor. In Figure 3 the source substrate diode is connected in a bridge circuit, an unbalance signal being detected by amplifier (14) and fed back *via* (FB) to the gate of the MOSFET (10) to influence the source-drain current L_{DS} until the temperature is restored to the fixed value. The unbalance signal also provides the sensor output. In an alternative arrangement the output of amplifier (14) is applied to the gate of an FET source follower connected in the source drain current path of MOSFET (10) to alter the voltage drop across the latter to maintain the fixed temperature.

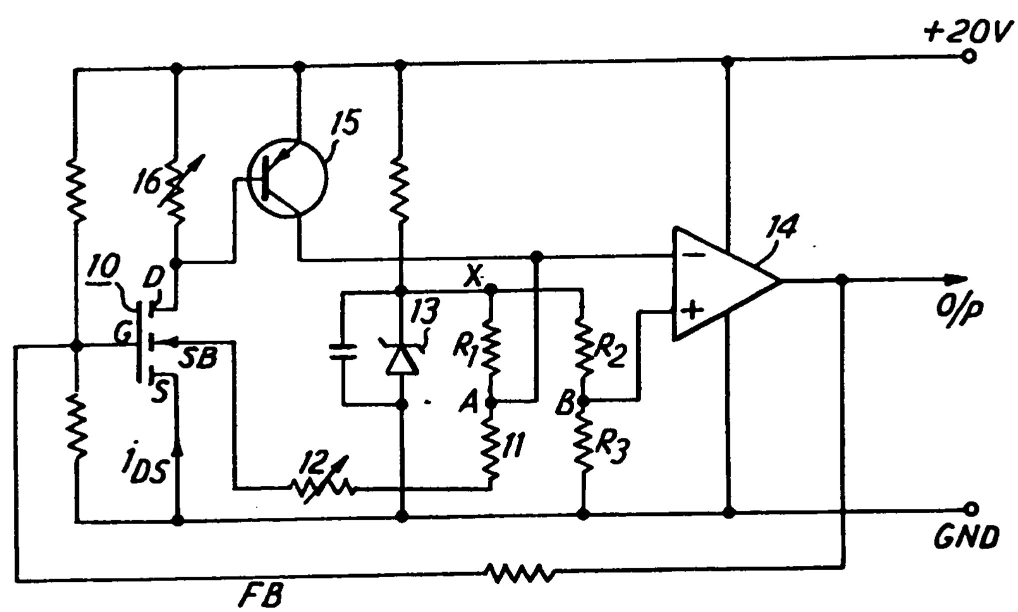

FIG.3

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

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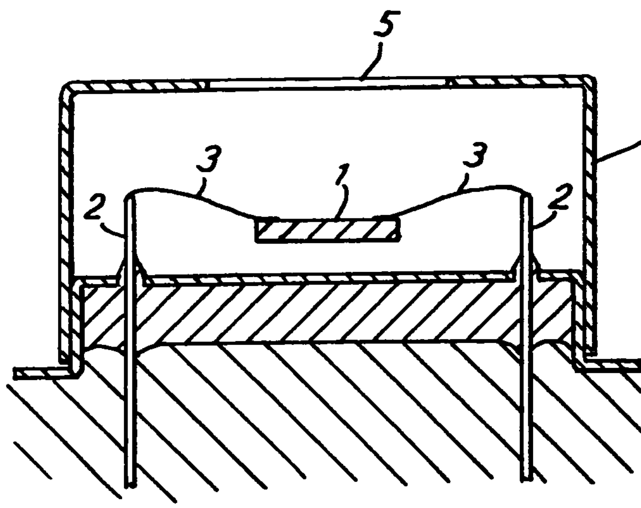


FIG.1

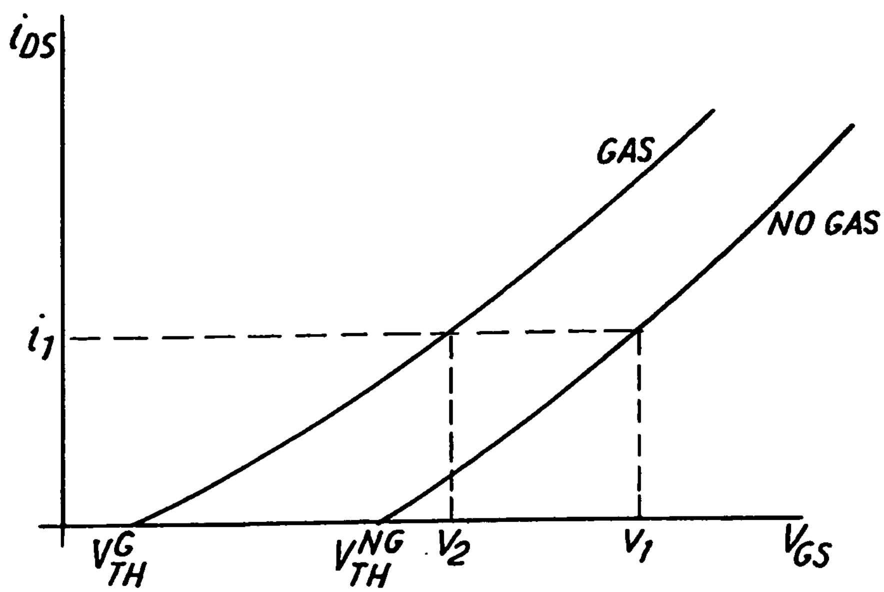
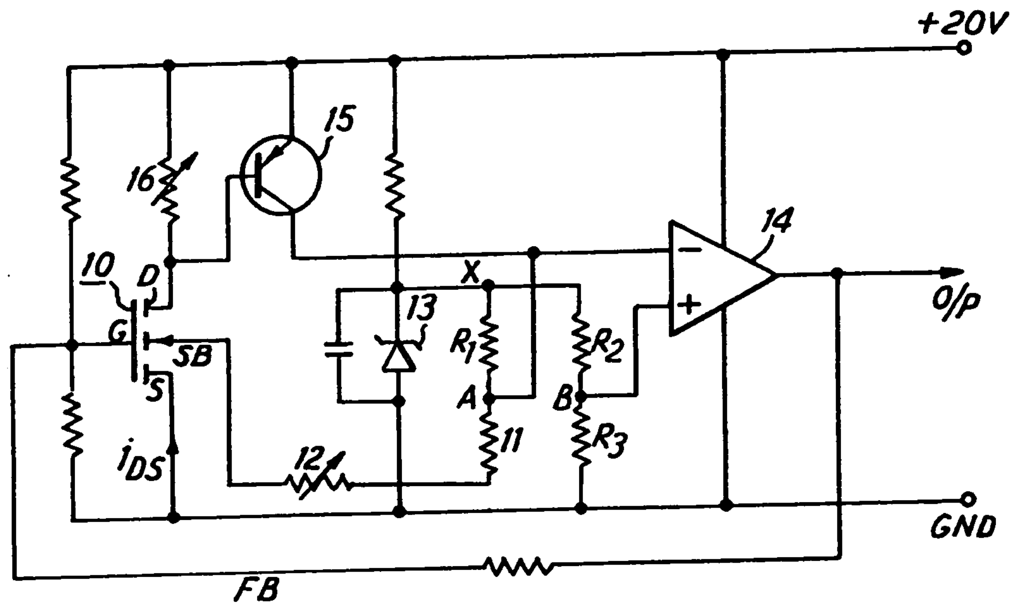


FIG.2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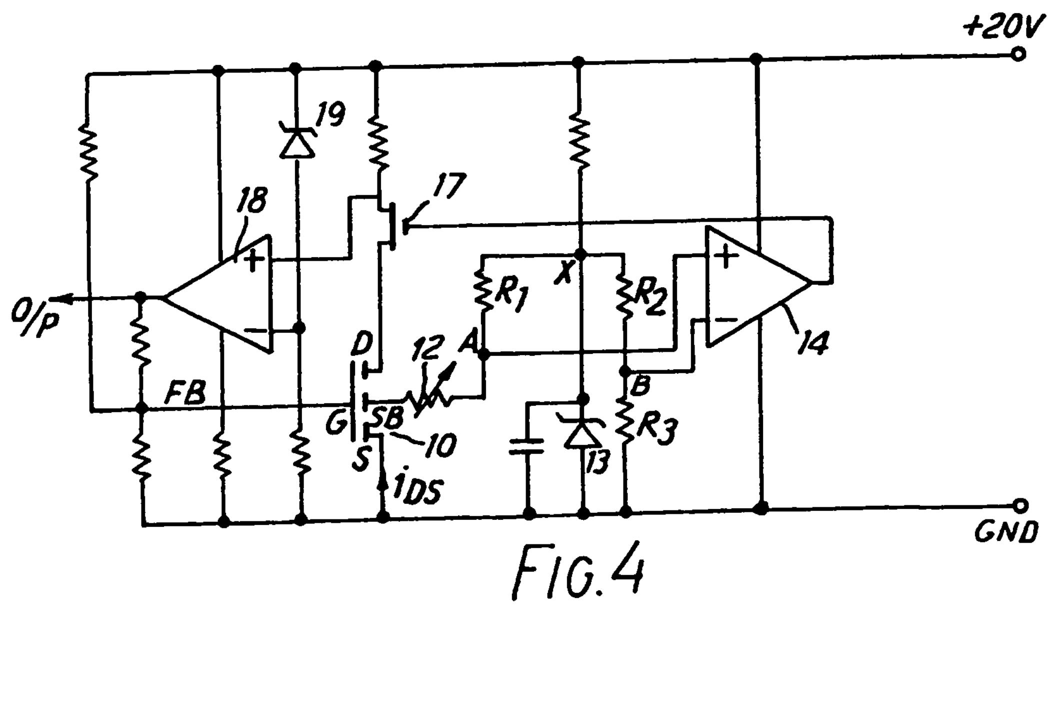
15
16
14
10
D
X
13
G
SB
R1
R2
S
A
B
O/P
iDS
12
11
R3
GND
FB

FIG.3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19
17
18
X
R1
R2
O/P
D
12
A
14
FB
B
G
SB
10
R3
S
13
iDS
GND

FIG.4

SPECIFICATION

Gas sensors

This invention relates to gas sensors and especially to gas sensors which operate at elevated temperatures.

It is known that MOSFETS may be used for the detection of gases, and in particular a palladium gate MOSFET may be used to detect hydrogen gas. Such detectors operate at elevated temperatures (typically 150°C). It may also be advantageous to operate a sensor, which normally operates at room temperature, at a constant temperature, just above the ambient temperature, to thereby reduce its temperature sensitivity.

If such detectors are to have wide spread use it is desirable that the circuits used to maintain the fixed working temperature should be as compact as possible and should consume as little power as possible.

It is an object of the present invention to provide an improved form of gas sensor.

According to the invention there is provided a gas sensor comprising a gas sensitive FET suitable for operation at a fixed temperature substantially above the ambient temperature, and a correction means capable of maintaining said FET substantially at said fixed temperature,

wherein the correction means comprises a first means capable of deriving a first signal indicative of a departure from said fixed temperature, a second means capable of deriving a second signal indicative of the source drain current, and wherein the said first and second signals are utilized to influence the power dissipated in the source drain path so that the temperature of the FET is maintained substantially at said fixed temperature, and the said second signal is utilized to influence the gate source voltage and is indicative of a detected gas. In order that the invention may be more fully understood specific embodiments thereof are now described by reference to the accompanying drawings of which,

Figure 1 shows a sectional side elevation view through a gas sensor and illustrates a means whereby the MOSFET used therein is mounted,

Figure 2 shows the i_{DS}-V_{GS} characteristics of the MOSFET both in the absence and the presence of a gas, and

Figures 3 and *4* illustrate two alternative circuits suitable for operation of the sensor.

In the examples described below the gas sensor is comprised of a palladium gate MOSFET, which typically operates at about 150°C and is suitable for the detection of hydrogen gas. In the present invention the MOSFET is maintained at this relatively high temperature by virtue of the heat dissipated in the source drain path. The circuits described by reference to Figures 3 and 4 ensure that the heat dissipated in the device is sufficient always to maintain its temperature at a desired value, even though the ambient temperature may fluctuate, and/or the source drain current may tend to change due to the presence of, or a change in the concentration of, hydrogen gas.

In order to minimise heat loss to the surroundings the MOSFET is freely suspended in a partially enclosed environment, as shown in Figure 1. The MOSFET 1 is suspended between electrically conducting support posts 2 by means of aluminium or gold wires 3 which for a 25 thou square chip are typically no more than about 0.001" in diameter. These wires may also constitute some of the electrical connections between the MOSFET and the additional circuits described below. A header 4 having an aperture 5 surrounds the supported MOSFET and serves to prevent undue air turbulence in the vicinity of the MOSFET whilst permitting free access to a desired gas.

Referring firstly to Figure 3 the gas sensitive MOSFET, in this case a palladium gate MOSFET, is shown at 10. The source - substrate diode, between the source (S) and the substrate (SB) of the MOSFET, together with a fixed resistor 11 and a variable resistor 12, constitute one arm of a constant voltage bridge, the three other arms in the bridge comprising respective fixed resistors R_1, R_2 and R_3. A Zener diode 13 sets the point X in the bridge at a fixed reference voltage with respect to ground, and a differential amplifier 14 amplifies any signal detected across the points A and B, resulting from a lack of balance in the bridge. The signal at the output of the amplifier 14 is fed back, via a feed-back path FB, to the gate G of the MOSFET, and also provides the output signal O/P from the sensor.

The resistance of the source - substrate (S-SB) diode is sensitive to temperature and the variable resistor 12 is adjusted to a suitable value such that the bridge is balanced when the desired temperature (i.e. 150°C in this case) is sensed. Although in this arrangement the source - substrate diode is forward biassed, it may alternatively be reversed biassed. In operation, therefore, if a change in the ambient temperature occurs, causing a departure from the desired temperature, then the resistance of the source - substrate diode changes accordingly, and the bridge becomes unbalanced. Feed back, via path, FB, however, causes a change in the gate source voltage, V_{GS}, of the device which in turn influences the source drain current i_{DS}, until the temperature is restored to the desired value.

As shown in Figure 2 the effect of hydrogen gas on the MOSFET is to change the threshold level V_{TH} of the i_{DS}-V_{GS} characteristic. On exposure of the device to gas therefore the source drain current i_{DS} attempts to rise from the value i_1, occurring in the absence of a gas, towards a different value in accordance with the new characteristic. This in turn causes the voltage difference across the differential amplifier 14 to drop which results in a reduction of the gate source voltage V_{GS}, applied to the device via the feedback path FB. A stable situation is obtained when the source drain current is restored to its original value i_1, the gate source voltage V_{GS} then assuming a value V_2 on the new characteristic. In the present arrangement the gate source voltage V_1 is about 2.5V at 150°C in the absence of gas, but falls to a value V_2 of about 0.6V when exposed to 10ppm H_2 gas. Since, however, the source drain current to maintained at a substantially constant level i_1 the

heat dissipated in the device, and so the temperature thereof, also remain substantially constant even though the concentration of hydrogen gas may fluctuate. The power consumption required to maintain the MOSFET chip at 150°C can be as little as 5mV. In this example the source drain current i_{DS} is monitored by a transistor 15, and if the current exceeds a certain limit, set by the variable resistor 16, the transistor 15 is turned on, and acts on the feedback loop, thereby preventing the MOSFET current from rising to a damaging level. The concentration of hydrogen gas detected by this arrangement is directly reflected in the level of the output signal, O/P, which is proportional to the gate source voltage V_{GS}. This output, however, also reflects changes occasioned by variations in the ambient temperature, and although this may be tolerated in certain applications, Figure 4 shows an arrangement whereby this problem is substantially overcome.

In the arrangement of Figure 4 the MOSFET is again shown at 10 and, as described above, the source - substrate diode (S-SB) thereof is included within one arm of a constant voltage bridge. As before, a variable resistor 12 is also included within this arm for the purpose of setting a desired temperature, and the three other arms include respective fixed resistors R_1, R_2 and R_3. Any unbalance in the bridge, due to a departure from the desired temperature, is detected across the differential amplifier 14 and the corresponding output therefrom applied to the gate of a further FET 17, connected as a source follower. This has the effect of altering the voltage drop across the MOSFET 10 until the power dissipated therein is sufficiently high or low to maintain its temperature at the desired level.

As before when the arrangement is exposed to hydrogen gas the drain source current i_1, passing through the MOSFET attempts to rise, thereby lowering the voltage difference across the differential amplifier 18, one input terminal thereto being maintained at a fixed reference level by the Zener diode 19. The output from amplifier 18 is fed back to the gate G of the MOSFET thereby restoring the source drain current to its original value i_1. As before the gate source voltage V_{GS} falls, e.g. to about 0.6V, on exposure of the MOSFET to about 10ppm H_2. In contrast to the circuit of Figure 3, however, the output O/P from the amplifier 18 reflects only the concentration of a detected gas, and is substantially unaffected by a change of ambient temperature.

The above described arrangements therefore are effective to maintain the temperature of the gas sensitive MOSFET at a desired value typically 150°C and although a particular MOSFET has been described, the invention could also be used in conjunction with other types of gas sensitive MOSFET, a MOSFET having a platinum gate for example which is also used for hydrogen detection.

CLAIMS

1. A gas sensor comprising a gas sensitive field effect device for operation at a substantially fixed temperature above ambient temperature and correction means for regulating the current in the drain source path of said device so as to maintain its temperature at said substantially fixed temperature, said correction means comprising circuit means for generating an electrical signal representative of a departure from said fixed temperature, said electrical signal being utilised to influence the power dissipated in the device to thereby maintain its temperature at said substantially fixed temperature, said electrical signal or a signal derived therefrom being received at an output location and being indicative of a gas to which the device is exposed.

2. A gas sensor according to Claim 1 wherein said electrical signal is utilised to influence the gate source voltage of said device.

3. A gas sensor according to Claim 1 including a further field effect device, connected in series with said gas sensitive device, as a source follower and being responsive to said electrical signal to influence the power dissipated in the device.

4. A gas sensor according to any one of Claims 1 to 3 wherein the gas sensitive field effect device is a MOSFET.

5. A gas sensor according to Claim 4 wherein the said circuit means comprises a bridge circuit responsive to a change in the resistance of the source substrate diode of the MOSFET.

6. A gas sensor substantially as herein before described by reference to and as illustrated in the accompanying drawings.

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